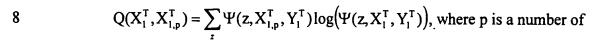WHAT IS CLAIMED IS:

1   1.   A method for maximum a posteriori (MAP) decoding of an input

2   information sequence based on a first information sequence received through a channel,

3   comprising:

4   iteratively generating a sequence of one or more decode results starting with an

5   initial decode result; and

6   outputting one of adjacent decode results as a decode of the input information

7   sequence if the adjacent decode results are within a compare threshold.

1   2.   The method of claim 1, wherein the iteratively generating comprises:

2   a. generating the initial decode result as a first decode result;

3   b. generating a second decode result based on the first decode result and a model

4   of the channel;

5   c. comparing the first and second decode results;

6   d. replacing the first decode result with the second decode result; and

7   e. repeating b-d if the first and second decode results are not within the compare

8   threshold.

1   3.   The method of claim 2, wherein the generating a second decode result

2   comprises searching for a second information sequence that maximizes a value of an

3   auxiliary function.

1   4.   The method of claim 3, wherein the auxiliary function is based on the

2   expectation maximization (EM) algorithm.

1   5.   The method of claim 4, wherein the model of the channel is a Hidden

2   Markov Model (HMM) having an initial state probability vector π and probability density

3   matrix (PDM) of $P(X,Y)$, where $X \in X$, $Y \in Y$ and elements of $P(X,Y)$,

4   $p_{ij}(X,Y) = Pr(j,X,Y \mid i)$, are conditional probability density functions of an information

5   element X of the second information sequence that corresponds to a received element Y

6   of the first information sequence after the HMM transfers from a state i to a state j, the

7   auxiliary function being expressed as:

15

8    $Q(X_1^T, X_{1,p}^T) = \sum_z \Psi(z, X_{1,p}^T, Y_1^T) \log(\Psi(z, X_1^T, Y_1^T))$, where p is a number of

9   iterations, $\Psi(z, X_1^T, Y_1^T) = \pi_{i_o} \prod_{t=1}^{T} p_{i_{t-1}i_t}(X_t, Y_t)$, T is a number of information elements

10   in a particular information sequence, z is a HMM state sequence i_0^T, π_{i_0} is the probability

11   of an initial state i_0, X_1^T is the second information sequence, $X_{1,p}^T$ is a second information

12   sequence estimate corresponding to a pth iteration, and Y_1^T is the first information

13   sequence.

1   6.   The method of claim 5, wherein the auxiliary function is expanded to be:

2    $$Q(X_1^T, X_{1,p}^T) = \sum_{t=1}^{T} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{t,ij}(X_{1,p}^T) \log(p_{ij}(X_t, Y_t)) + C$$
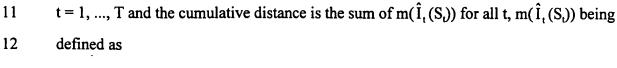
3   where C does not depend on X_1^T and

4    $$\gamma_{t,ij}(X_{1,p}^T) = \alpha_i(X_{1,p}^{t-1}, Y_1^{t-1}) p_{ij}(X_{t,p}, Y_t) \beta_j(X_{t+1,p}^T, Y_{t+1}^T)$$

5   where $\alpha_i(X_{1,p}^t, Y_1^T)$ and $\beta_j(X_{t+1,p}^T, Y_{t+1}^T)$ are the elements of forward and backward

6   probability vectors defined as

7    $$\alpha(X_1^t, Y_1^t) = \pi \prod_{i=1}^{t} P(X_i, Y_i), \text{ and } \beta(X_1^T, Y_1^T) = \prod_{j=t}^{T} P(X_j, Y_j) \mathbf{1}, \quad \pi \text{ is an}$$

8   initial probability vector, $\mathbf{1}$ is the column vector of ones.

1   7.   The method of claim 6, wherein a source of an encoded sequence is a

2   trellis code modulator (TCM), the TCM receiving a source information sequence I_1^T and

3   outputting X_1^T as an encoded information sequence that is transmitted, the TCM defining

4    $X_t = g_t(S_t, I_t)$ where X_t and I_t are the elements of X_1^T and I_1^T for each time t, respectively, S_t

5   is a state of the TCM at t, and $g_t(.)$ is a function relating X_t to I_t and S_t, the method

6   comprising:

7   generating, for iteration p+1, a source information sequence estimate $I_{1,p+1}^T$ that

8   corresponds to a sequence of TCM state transitions that has a longest cumulative distance

9    $L(S_{t-1})$ at t = 1 or $L(S_0)$, wherein a distance for each of the TCM state transitions is

10   defined by $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for the TCM state transitions at each t for
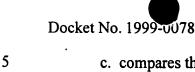
11 $t = 1, ..., T$ and the cumulative distance is the sum of $m(\hat{I}_t(S_t))$ for all t, $m(\hat{I}_t(S_t))$ being

12 defined as

13
$$m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \sum_{j=1}^{n_c} \gamma_{t,ij}(I_{I,p}^T) \log p_{c,ij}(Y_t \mid X_t(S_t)), \text{ for each } t = 1, 2, ..., T, \text{ where}$$

14 $X_t(S_t) = g_t(S_t, \hat{I}_t(S_t))$, n_c is a number of states in an HMM of the channel and

15 $p_{c,ij}(Y_t \mid X_t(S_t))$ are channel conditional probability density functions of Y_t when $X_t(S_t)$ is

16 transmitted by the TCM, $I_{I,p+1}^T$ being set to a sequence of $\hat{I}_t$ for all t.

1   8.   The method of claim 7, wherein for each $t = 1, 2, ..., T$, the method

2   comprises:

3   generating $m(\hat{I}_t(S_t))$ for each possible state transition of the TCM;

4   selecting state trajectories that correspond to largest $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$

5   for each state as survivor state trajectories; and

6   selecting $\hat{I}_t(S_t)$s that correspond to the selected state trajectories as $I_{t,p+1}(S_t)$.

1   9.   The method of claim 8, further comprising:

2   a. assigning $L(S_T) = 0$ for all states at $t = T$;

3   b. generating $m(\hat{I}_t(S_t))$ for all state transitions between states S_t and all possible

4   states S_{t+1};

5   c. selecting state transitions between the states S_t and S_{t+1} that have a largest

6   $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ and $\hat{I}_{t+1}(S_{t+1})$ that correspond to the selected state

7   transitions;

8   d. updating the survivor state trajectories at states S_t by adding the selected state

9   transitions to the corresponding survivor state trajectories at state S_{t+1};

10   e. decrementing t by 1;

11   f. repeating b-e until $t = 0$; and

12   g. selecting all the $\hat{I}_t(S_t)$ that correspond to a survivor state trajectory that

13 corresponding to a largest $L(S_t)$ at $t = 0$ as $I_{I,p+1}^T$.

1   10.   The method of claim 6, wherein the channel is modeled as $P_c(Y \mid X) =$

2   $P_c B_c(Y \mid X)$ where P_c is a channel state transition probability matrix and $B_c(Y \mid X)$ is a

3   diagonal matrix of state output probabilities, the method comprising for each $t = 1, 2, ...,$

4   T:

5   generating $\gamma_{t,i}(I_{1,p}^T) = \alpha_i(Y_1^t \mid I_{1,p}^t)\beta_i(Y_{t+1}^T \mid I_{t+1,p}^T)$;

6   selecting an $\hat{I}_t(S_t)$ that maximizes $L(S_t)=L(S_{t+1})+ m(\hat{I}_{t+1}(S_{t+1}))$, where $m(\hat{I}_t(S_t))$

7   is defined as

8    $m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \gamma_{t,i}(I_{1,p}^T)\beta_j(Y_t \mid X_t(S_t))$, n_c being a number of states in an HMM of

9   the channel;

10   selecting state transitions between states S_t and S_{t+1} that corresponds to a largest

11    $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$; and

12   forming survivor state trajectories by connecting selected state transitions.

1   11.   The method of claim 10, further comprising:

2   selecting $\hat{I}_t(S_t)$ that corresponds to a survivor state trajectory at $t = 0$ that has the

3   largest $L(S_t)$ as $I_{1,p+1}^T$ for each pth iteration;

4   comparing $I_{1,p}^T$ and $I_{1,p+1}^T$; and

5   outputting $I_{1,p+1}^T$ as the second decode result if $I_{1,p}^T$ and $I_{1,p+1}^T$ are within the

6   compare threshold.

1   12.   A maximum a posteriori (MAP) decoder that decodes a transmitted

2   information sequence using a received information sequence received through a channel,

3   comprising:

4   a memory; and

5   a controller coupled to the memory, the controller iteratively generating a

6   sequence of one or more decode results starting with an initial decode result, and

7   outputting one of adjacent decode results as a decode of the input information sequence if

8   the adjacent decode results are within a compare threshold.

1   13.   The decoder of claim 12, wherein the controller:

2   a. generates the initial decode result as a first decode result;

3   b. generates a second decode result based on the first decode result and a model

4   of the channel;

5   c. compares the first and second decode results;

6   d. replaces the first decode result with the second decode result; and

7   e. repeats b-d until the first and second decode result are not within the compare

8 threshold.

1   14.   The decoder of claim 13, wherein the controller searches for information

2 sequence that maximizes a value of an auxiliary function.

1   15.   The decoder of claim 14, wherein the auxiliary function is based on

2 expectation maximization (EM).

1   16.   The decoder of claim 15, wherein the model of the channel is a Hidden

2 Markov Model (HMM) having an initial state probability vector π and probability density

3 matrix (PDM) of $P(X,Y)$, where $X \in X$, $Y \in Y$ and elements of $P(X,Y)$,

4 $p_{ij}(X,Y) = Pr(j,X,Y \mid i)$, are conditional probability density functions of an information

5 element X of the second information sequence that corresponds to a received element Y

6 of the first information sequence after the HMM transfers from a state i to a state j, the

7 auxiliary function being expressed as:

8 $$Q(X_1^T, X_{1,p}^T) = \sum_z \Psi(z, X_{1,p}^T, Y_1^T) \log\left(\Psi(z, X_1^T, Y_1^T)\right),$$ where p is a number of

9 iterations, $\Psi(z, X_1^T, Y_1^T) = \pi_{i_0} \prod_{t=1}^{T} p_{i_{t-1}, i_t}(X_t, Y_t)$, T is a number of information elements

10 in a particular information sequence, z is a HMM state sequence i_0^T, π_{i_0} is the probability

11 of an initial state i_0, X_1^T is the second information sequence, $X_{1,p}^T$ is a second information

12 sequence estimate corresponding to a pth iteration, and Y_1^T is the first information

13 sequence.

1   17.   The decoder of claim 16, wherein the auxiliary function is expanded to be:

2 $$Q(X_1^T, X_{1,p}^T) = \sum_{t=1}^{T} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{t,ij}(X_{1,p}^T) \log(p_{ij}(X_t, Y_t)) + C$$

3 where C does not depend on X_1^T and

4 $$\gamma_{t,ij}(X_{1,p}^T) = \alpha_i(X_{1,p}^{t-1}, Y_1^{t-1}) p_{ij}(X_{t,p}, Y_t) \beta_j(X_{t+1,p}^T, Y_{t+1}^T)$$

5 where $\alpha_i(X_{1,p}^t, Y_1^T)$ and $\beta_j(X_{t+1,p}^T, Y_{t+1}^T)$ are the elements of forward and backward

6 probability vectors defined as

7
$$\alpha(X_1^t, Y_1^t) = \pi \prod_{i=1}^{t} P(X_i, Y_i), \text{ and } \beta(X_{t+1}^T, Y_{t+1}^T) = \prod_{j=t+1}^{T} P(X_j, Y_j) \mathbf{1}, \pi \text{ is an initial}$$

8   probability vector, **1** is the column vector of ones.

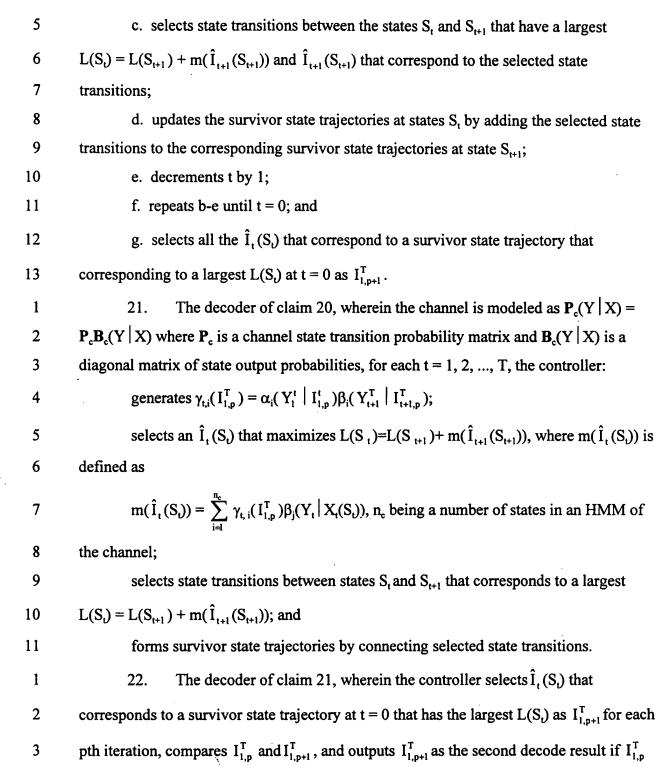1   18.   The decoder of claim 17, wherein a source of an encoded sequence is a

2   trellis code modulator (TCM), the TCM receiving a source information sequence I_1^T and

3   outputting X_1^T as an encoded information sequence that is transmitted, the TCM defining

4      $X_t = g_t(S_t, I_t)$ where X_t and I_t are the elements of X_1^T and I_1^T for each time t, respectively, S_t

5   is a state of the TCM at t, and $g_t(.)$ is a function relating X_t, to I_t and S_t, the controller

6   generates, for iteration p+1, an input information sequence estimate $I_{1,p+1}^T$ that

7   corresponds to a sequence of TCM state transitions that has a longest cumulative distance

8      $L(S_{t-1})$ at t = 1 or $L(S_0)$, wherein a distance for each of the TCM state transitions is

9   defined by $L(S_{t+1}) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for the TCM state transitions at each t for

10   t = 1, ..., T and the cumulative distance is the sum of $m(\hat{I}_t(S_t))$ for all t, $m(\hat{I}_t(S_t))$ being

11   defined as

12
$$m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \sum_{j=1}^{n_c} \gamma_{t,ij}(I_{1,p}^T) \log p_{c,ij}(Y_t | X_t(S_t)), \text{ for each t = 1, 2, ..., T, where}$$

13     $X_t(S_t) = g_t(S_t, \hat{I}_t(S_t))$, n_c is a number of states in an HMM of the channel and

14     $p_{c,ij}(Y_t | X_t(S_t))$ are channel conditional probability density functions of Y_t when $X_t(S_t)$ is

15   transmitted by the TCM, $I_{1,p+1}^T$ being set to a sequence of $\hat{I}_t$ for all t.

1   19.   The decoder of claim 18, wherein for each t = 1, 2, ..., T, the controller

2   generating $m(\hat{I}_t(S_t))$ for each possible state transition of the TCM, selecting state

3   trajectories that correspond to largest $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ for each state as

4   survivor state trajectories, and selecting $\hat{I}_{t+1}(S_{t+1})$s that correspond to the selected state

5   trajectories as $I_{t+1,p+1}(S_{t+1})$.

1   20.   The decoder of claim 19, wherein the controller:

2   a. assigns $L(S_T)=0$ for all states at t = T;

3   b. generates $m(\hat{I}_t(S_t))$ for all state transitions between states S_t and all possible

4   states S_{t+1};

5   c. selects state transitions between the states S_t and S_{t+1} that have a largest

6    $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$ and $\hat{I}_{t+1}(S_{t+1})$ that correspond to the selected state

7   transitions;

8   d. updates the survivor state trajectories at states S_t by adding the selected state

9   transitions to the corresponding survivor state trajectories at state S_{t+1};

10   e. decrements t by 1;

11   f. repeats b-e until t = 0; and

12   g. selects all the $\hat{I}_t(S_t)$ that correspond to a survivor state trajectory that

13   corresponding to a largest $L(S_t)$ at t = 0 as $I_{1,p+1}^T$.

1   21.   The decoder of claim 20, wherein the channel is modeled as $P_c(Y|X) =$

2    $P_c B_c(Y|X)$ where P_c is a channel state transition probability matrix and $B_c(Y|X)$ is a

3   diagonal matrix of state output probabilities, for each t = 1, 2, ..., T, the controller:

4   generates $\gamma_{t,i}(I_{1,p}^T) = \alpha_i(Y_1^t | I_{1,p}^t)\beta_i(Y_{t+1}^T | I_{t+1,p}^T)$;

5   selects an $\hat{I}_t(S_t)$ that maximizes $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$, where $m(\hat{I}_t(S_t))$ is

6   defined as

7    $m(\hat{I}_t(S_t)) = \sum_{i=1}^{n_c} \gamma_{t,i}(I_{1,p}^T)\beta_j(Y_t | X_t(S_t))$, n_c being a number of states in an HMM of

8   the channel;

9   selects state transitions between states S_t and S_{t+1} that corresponds to a largest

10    $L(S_t) = L(S_{t+1}) + m(\hat{I}_{t+1}(S_{t+1}))$; and

11   forms survivor state trajectories by connecting selected state transitions.

1   22.   The decoder of claim 21, wherein the controller selects $\hat{I}_t(S_t)$ that

2   corresponds to a survivor state trajectory at t = 0 that has the largest $L(S_t)$ as $I_{1,p+1}^T$ for each

3   pth iteration, compares $I_{1,p}^T$ and $I_{1,p+1}^T$, and outputs $I_{1,p+1}^T$ as the second decode result if $I_{1,p}^T$

4   and $I_{1,p+1}^T$ are within the compare threshold.